CATHODE FOR ELECTRON TUBE AND PREPARING METHOD THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a cathode for an electron tube and a method of preparing the same, and more particularly, to an oxide-coated, thermion-emitting cathode (also called an oxide cathode) with improved life characteristics, which is widely employed for general Braun tubes.

2. Description of the Related Art

FIG. 1 is a schematic sectional view of a typical cathode for an electron tube. The cathode includes a base metal 12 having the shape of a circular plate, a cylindrical sleeve 13 which is provided below the base metal 12 to support the base metal 12 and has a heater 14, i.e., a heating source of the cathode, incorporated therein, and an electron-emitting material layer 11 adhering to the top of the base metal 12. Since such an oxide cathode has a low work function, it has an advantage of operating at a relatively low temperature (700-800°C) so that it is widely used for general Braun tubes.

In general, a conventional oxide cathode for an electron tube is constructed such that the electron-emitting material layer 11, e.g., an alkaline earth metal carbonate having barium (Ba) as a main component, preferably a ternary carbonate having a basic composition of (Ba, Sr, Ca)CO_3 or a binary carbonate having a basic composition of (Ba, Sr)CO_3, is coated on a base metal containing nickel (Ni) as a main component and a small amount of silicon (Si) or magnesium (Mg) as a reducing agent. The carbonate is converted into an oxide by evaporation or activation in the course of manufacture of a cathode for an electron tube to be served as an electron-emitting material layer.

The following description concerns a general procedure of preparing an oxide cathode and the principle of electron emission.

Carbonate powder containing barium carbonate as a main component is mixed in an organic solvent in which a binder such as nitrocellulose is dissolved. The resulting mixture is attached to a base metal using a spraying or electrodeposition method. The resulting structure is installed at an electron gun, which is provided in an electron tube. During evaporation for making the inside of the electron tube vacuous, the carbonate is heated to about 1000°C by a heater. Here, the barium carbonate is converted into barium oxide as follows.

$$BaCO_3 \rightarrow BaO + CO_2 \quad (1)$$

The barium oxide reacts with Si and Mg, which is a reducing agent contained in the base metal, at its boundary contacting the base metal during the operation of a cathode, and is reduced as the following chemical equations, thereby producing free barium. The barium contributes to the emission of electrons.

$$BaO + Mg \rightarrow MgO + Ba \quad (2)$$

$$4BaO + Si \rightarrow Ba_2SiO_4 + 2Ba \quad (3)$$

Since free barium serves as an electron donor, the oxide cathode is physically an N-type semiconductor during operation. Generally, a semiconductor generates Joule heat due to electrical resistance at a high current density. If such Joule heat is generated over a prolonged period, a raw material of a cathode may be evaporated or melted by self-heating due to the generated Joule heat, resulting in deterioration of the cathode. Thus, the use of a general oxide cathode at a high current density, which is for the purpose of enhancing electron emission, sharply decreases life characteristics of the cathode due to deterioration of the cathode.

As understood from the formulas (2) and (3), byproducts such as MgO, Ba_2SiO_4 or the like as well as free barium are also produced. These byproducts are formed around the interface between an electron-emitting material layer and a base metal to form an intermediate product. The intermediate product severs as a barrier to prevent diffusion of Mg or Si, thereby making it difficult to generate free Ba, which contributes to electron emission. Also, the intermediate product undesirably results in shortening of the life span of the oxide cathode. Further, the intermediate

product has high resistance and prevents the flow of current for emitting electrons and thus limits current density.

In order to keep in step with the recent trend for a Braun tube with a larger-sized screen, longer lifetime, high-definition, and high-luminance, there is an increasing need for a cathode having a longer lifetime at a high current density.

However, conventional oxide cathodes are not capable of satisfying this need due to the aforementioned disadvantages with respect to performance and life span.

An impregnated cathode is known for its high current density and long life span, but the manufacturing process therefor is complex and its operating temperature is over 1000°C, higher than that of oxide cathodes. Accordingly, since it is required that the cathode be made of a material with a much higher melting point which is expensive, its practical use is impeded. Thus, a great deal of research has gone into providing the high current density and lengthening the life span of an oxide cathode by development improved cathode oxides that are cheapest from the viewpoint of practicality.

For example, Korean Patent Publication No. 1991-17481 (claiming priority from Japanese Patent Application No. 2-56855) discloses a cathode for an electron tube in which a metal layer made of at least one kind of metal such as tungsten (W), molybdenum (Mo) or the like is deposited on a base metal and a rare-earth metal oxide such as Sc_2O_3 is dispersed in an electron-emitting material layer. In the cathode disclosed in this patent, a rare-earth metal such as Sc decomposes an intermediate product and W itself acts as a reducing agent, contributing to generation of free Ba, thereby improving high current density and life characteristics.

However, while W acting as a reducing agent generates free Ba, it also produces byproducts as expressed in the following formula (4), so that cathode characteristics, in particular, life span, sharply decrease as a cathode operation time increases.

$$2BaO + 1/3W \quad 1/3Ba_3WO_6+Ba$$

Japanese Patent Laid-Open Publication No. Hei 8-50849 (corresponding to EP 0685868 A1) discloses a cathode for an electron tube which is a so-called HIP

(hot isostatic press) cathode. In other words, in operating a cathode with an electron-emitting layer fabricated by mixing metallic nickel powder and a carbonate and forming the same under high-temperature and high-pressure conditions, the electron-emitting layer itself has a conductivity because of metallic nickel, thereby providing the cathode with a long life at a high current density. However, such a cathode has a higher operating temperature, that is, approximately 850°C, which is approximately 50°C higher than the conventional oxide cathode, and its manufacturing process is complicated, resulting in an increase in manufacturing cost.

Japanese Patent Laid-Open Publication No. Hei 6-28968 (corresponding to EP 0560436 A1) discloses an oxide cathode with improved life characteristic, in which a conductive path based on percolation is formed by adding 20 to 80% by volume of spherical metal particles to an electron-emitting material layer used for a conventional oxide cathode. However, in order to achieve a percolation effect by addition of spherical metallic particles, at least 30% by weight of metal particles should be contained in the electron-emitting material layer, that is, a relative content of the electron-emitting material layer is greatly reduced, lowering initial emission of the cathode.

S.N.B. Hodgson et al. discloses an oxide cathode having a percolation path by adding 2.5 to 5% by volume of needle-shaped nickel particles to an electron-emitting material layer, in a paper entitled "Progress on the percolation Cathode", IDW 99 Proceedings of The Sixth International Display Workshops CRT6-4 (Late-News Paper). However, the oxide cathode disclosed by Hodgson et al. having an electron-emitting layer formed by a general spray method disadvantageously has large surface roughness of the cathode.

However, since a spraying method uses only force sprayed by air pressure without using any other pressure, it is limited in obtaining a uniform and dense coating film. More specifically, the structure of an electron-emitting material layer attached by a spraying method is shown in FIGS. 2 and 3. FIG. 2 is an electron microscopy photograph of the section, which is enlarged 400 times, of an

electron-emitting material layer attached by a spraying method. As shown in FIG. 2, the size of the pore between particles is nonuniform, the surface is very coarse, and the texture is sparse. FIG. 3 is an electron microscopy photograph of the surface texture, which is enlarged 3000 times, of the electron-emitting material layer of FIG. 2. It can be confirmed again that the size of the pore between particles is very nonuniform.

When the surface of a cathode is coarse, the distribution of electron emission beams becomes nonuniform, resulting in nonunformity in brightness distribution due to a local difference in electron emissions on the screen of a cathode ray tube, which is caused by a moire phenomenon in which patterns are generated due to interference between electron beams and screen dots. In addition, when a cathode ray tube is driven for a long time, sintering of the cathode progresses. Here, if the texture of the cathode is not dense, pores initially formed are collapsed and shrunk, increasing the distance between the cathode and the G1 electrode. Consequently, the potential difference, which is set to control an emitted electron beam, between the cathode and the G1 electrode changes, which causes deterioration of a life characteristic and degradation of brightness due to a decreases in the amount of a charge emitted.

As described above, when a cathode with such an electron-emitting material layer having nonuniform particle size, pore size and smoothness is installed at an electron gun, defects occurs in a product, and the reliability in quality decreases. However, the above-referenced cathodes cannot solve these problems at all.

SUMMARY OF THE INVENTION

To solve the above-described problems, it is an object of the present invention to provide an oxide cathode which can suppress degradation due to self-heating of the cathode by reducing generation of Joule heat due to intrinsic resistance of the cathode, which can minimize a voltage difference due to a difference in the distance between the cathode and a G1 electrode and which is improved in shrinking in the

case of long operation, thereby improving life characteristics at a high current density and reducing degradation of brightness for an electron tube.

To achieve the above object, there is provided a cathode for an electron tube, including a base metal and an electron-emitting material layer attached on the base metal, wherein the electron-emitting material layer comprises a needle-shaped conductive material and a surface roughness, which is measured from the distance between a highest point and a lowest point of the surface of the electron-emitting material layer, is controlled to be no greater than 10 μm.

In an embodiment of the present invention, the needle-shaped conductive material preferably has specific resistance of 10^{-1} Ωcm or less.

Preferably, the needle-shaped conductive material is at least one selected from the group consisting of carbon, indium tin oxide, nickel, magnesium, rhenium, molybdenum and platinum.

More preferably, the needle-shaped conductive material is a carbon material.

Also, the needle-shaped conductive material is preferably selected from the group consisting of carbon nanotube, carbon fiber and graphite fiber.

The content of the needle-shaped conductive material contained in the electron-emitting material layer is preferably in the range of 0.01 to 30% by weight based on the weight of the electron-emitting material layer.

The thickness of the electron-emitting material layer is preferably 30-80 μm.

Preferably, the electron-emitting material layer is attached on the base metal by one of printing, electrodeposition and painting.

More preferably, the electron-emitting material layer is attached to the base metal by a screen printing method.

In an embodiment of the present invention, the cathode may further include a metal layer having nickel having a smaller grain size than the metal base, between the metal base and the electron-emitting material layer.

Preferably, the metal layer further includes 1 to 10% by weight of tungsten and 0.01 to 1% by weight of aluminum, based on the weight of nickel.

The thickness of the metal layer is preferably 1-30 μm, and the metal layer may further include at least one metal selected from the group consisting of tantalum (Ta), chrome (Cr), magnesium (Mg), silicon (Si) and zirconium (Zr).

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a schematic diagram of a typical cathode for an electron tube;

FIG. 2 is an electron microscopy photograph of the section of a conventional cathode, which is enlarged 400 times;

FIG. 3 is an electron microscopy photograph of the surface coating of the conventional cathode of FIG. 2, which is enlarged 3000 times;

FIG. 4 is a schematic diagram showing the section of a cathode layer according to an embodiment of the present invention;

FIG. 5 is a schematic diagram showing the section of a cathode layer according to another embodiment of the present invention;

FIG. 6 is an electron microscopy photograph of the section of the cathode according to an embodiment of the present invention, which is enlarged 400 times;

FIG. 7 is an electron microscopy photograph of the surface coating of the cathode of FIG. 4, which is enlarged 3000 times;

FIG. 8 is a graph showing the evaluation result of a change in life characteristics relative the operating time of cathodes according to Examples of the present invention and Comparative Example;

FIG. 9 shows a mean time to failure (MTTF) mode estimated from the evaluation result of life characteristics of cathodes according to Examples of the present invention and Comparative Example;

FIG. 10 shows a variation in cut-off voltage of cathodes according to Examples of the present invention and Comparative Example; and

FIG. 11 shows initial emission characteristics of cathodes according to Examples of the present invention and Comparative Example.

DETAILED DESCRIPTION OF THE INVENTION

An oxide cathode for an electron tube according to the present invention will now be described in more detail with reference to the accompanying drawings.

The present invention is proposed to remove essential causes of degradation of life characteristics at a high current density or to reduce their effects. The oxide cathode according to the present invention is characterized in that an electron-emitting material layer composed of needle-shaped conductive particles is formed to form a conductive path more effectively than in the case of an electron-emitting material layer composed of spherical conductive particles, generation of Joule heat due to intrinsic resistance of the oxide cathode is suppressed by controlling the surface roughness of the electron-emitting material layer to be in a predetermined range to thus suppress deterioration due to self-heating of the cathode, a voltage difference due to a gap between the cathode and a G1 electrode is minimized, an extended life span is achieved at a high current density and degradation in brightness is prevented by solving the problem of shrinkage of the cathode when the cathode is driven for a long time of period.

FIGS. 4 and 5 are schematic diagrams of an oxide cathode layer according to an embodiment of the present invention. In detail, FIG. 4 shows the structure of an oxide cathode having an electron-emitting layer containing a needle-shaped conductive material 41 directly coated on a metal base, and FIG. 5 shows the structure of a cathode having an intermediate layer having nickel metal 52 as a main component between a metal base and an electron-emitting material layer containing a needle-shaped conductive material 51. In addition to the nickel metal 52, the intermediate layer may further include a high-melting point metal or reducing agent 53 for increasing the mechanical strength of the cathode.

Whereas an electron-emitting material layer of a conventional cathode is formed of a carbonate containing barium (Ba) as a main component, e.g., a ternary

carbonate (Ba, Sr, Ca)CO_3 or a binary carbonate (Ba, Sr)CO_3, the oxide cathode according to the present invention contains an electron-emitting material layer formed of a needle-shaped conductive material, as shown in FIGS. 4 and 5. Since the needle-shaped conductive material is an electrically conducting material having specific resistance of 10^{-1} Ωcm or less and is advantageous in forming a conductive path in an electron-emitting material layer than in the spherical conductive material, a much smaller conductive material can sufficiently prevent degradation by Joule heat during operation of the cathode compared to the case of a spherical conductive material. Also, since the content of the conductive material is reduced, the amount of an electron-emitting material is relatively reduced. Accordingly, initial emission characteristics are improved.

Further, in the oxide cathode according to the present invention, the surface roughness of an electron-emitting material layer, that is, a distance between the highest point and the lowest point of the electron-emitting material layer, is controlled to be 10 μm, a voltage difference due to a gap between a cathode and a G1 electrode can be minimized. Also, since the shrinking of a cathode due to a long operation can be prevented, a life characteristic and degradation of brightness can be improved, and defects caused by a difference between a voltage applied to a cathode and a voltage applied to a G1 electrode can be prevented.

A manufacturing process of an oxide cathode according to the present invention will now be briefly described.

Preparation of carbonate paste

Carbonate powder containing Ba carbonate as a main component and needle-shaped conductive powder are homogenously mixed with an organic binder and an organic solvent to prepare a carbonate paste. The content of the needle-shaped conductive powder is preferably 0.01 to 30% by weight, based on the total weight of the carbonate paste. If the amount of the conductive powder is less than 0.01% by weight, the electron-emitting material layer cannot have sufficient electrical conductivity, making it difficult to reduce the amount of Joule heat generated due to intrinsic resistance. If the amount of conductive powder is greater

than 30 wt. %, the amounts of Ba and Ba compounds are relatively reduced, adversely affecting electron emission characteristics.

Usable examples of the needle-shaped conductive powder for use in the oxide cathode according to the present invention include carbon materials such as carbon nanotube, carbon fiber or graphite fiber, needle-shaped indium tin oxides or needle-shaped metals such as nickel, magnesium, rhenium, molybdenum or platinum. In other words, any needle-shaped material having specific resistance of 10^{-1} Ωcm or less is preferably used in the present invention.

In an embodiment of the present invention, a carbon material such as carbon nanotube is particularly preferred because it is stable at higher temperatures and has a large aspect ratio.

Longer needle-shaped powder particles are preferred because they can more effectively form a conductive channel. In other words, since the longer needle-shaped powder particles are more advantageous in forming a conductive channel, use of a trace of a conductive material can effectively impart conductivity.

Any carbonate widely used for preparing an oxide cathode can be used. For example, carbonate having a basic composition of (Ba, Sr, Ca)CO_3 or (Ba, Sr)CO_3 can be used. Preferably, the amount of carbonate contained in the printing mixture, i.e., the paste, is 40-60 wt. % based on the total weight of the paste. If the amount of carbonate is less than 40 wt. %, it is difficult to attain a desirable electron emission characteristic. If the amount of carbonate is greater than 60 wt. %, the fluidity of the mixture decreases, making uniform printing difficult.

A binder used in a typical spraying method can be used as the binder added to the printing mixture. For example, nitrocellulose or ethylcellulose can be used. Preferably, the amount of the binder is 1-10 wt. % based on the total weight of the paste. When the amount of the binder is less than 1 wt. %, adhesive strength decreases after drying. When the amount of the binder is greater than 10 wt. %, an electron emission characteristic is deteriorated due to a decrease in a degree of a vacuum within a cathode ray tube decreases and residual carbon.

Since the printing mixture should be in a paste state, a highly volatile organic solvent used in a conventional spraying method cannot be used as the organic solvent added to the printing mixture. For example, terpinol, butyl carbitol acetate or a combination thereof can be used. Preferably, the amount of the organic solvent is 30-50 wt. % based on the total weight of the paste so that a paste state suitable for printing can be attained.

Preparation of metal layer on metal base

Next, a metal layer is selectively formed. In other words, an electron-emitting material layer may be directly coated on the metal base. Otherwise, for distributed formation of intermediate products during cathode operation and acquisition of a distribution path of a reducing agent, a metal layer is first formed and an electron-emitting material layer is then formed. Formation of a metal layer will now be described briefly.

Nickel powder is mixed optionally with predetermined amounts of tungsten and/or aluminum as a reducing agent, and is then mixed well with an organic binder and a liquid-type organic solvent to prepare a paste. The paste is applied on the cathode base and is subjected to heat treatment under vacuum or inert atmosphere, thereby obtaining organic matter removed metal layer. Methods of applying the paste for forming a metal layer on the metal base are not specifically limited, including printing, spraying, electrodeposition and painting, but the printing method is most preferred in view of adjustment of surface roughness of a cathode to be in a predetermined range.

In order to increase bondability between the metal layer and the electron-emitting material layer, the metal layer may have a gauze or dot printing pattern. In the case of screen printing, such a pattern can be easily obtained by using a pattern incorporated printing gauze.

The thickness of a metal layer made from nickel is preferably in the range of 1 to 30 μm, particularly 2 to 3 μm in the case of a pure nickel metal layer in which no reducing agent is used. In the case of using a reducing agent, good characteristics can be obtained by a relatively thicker metal layer.

The reason of adding a reducing agent such as tungsten or aluminum to the paste for forming a metal layer is as follows. Even if the nickel metal layer can impart a sufficient distribution effect to reaction products during cathode operation, a distance between the metal base and the electron-emitting material layer may increase depending on the thickness of the nickel metal layer, causing the reducing agent to distribute slowly, finally resulting in poor electron emissions. To attain stable, good electron emission characteristics, 1 to 10% by weight of tungsten is preferably added or 0.01 to 1% by weight of aluminum is preferably added, based on the weight of nickel powder. Instead of tungsten or aluminum, use of a reducing metal such as tantalum, chrome, magnesium or silicon can give the same effect.

Preparation of cathode

The thus-formed carbonate paste containing the needle-shaped conductive material is applied on the metal base or on the nickel metal layer formed on the metal base, thereby completing a cathode. In a cathode for an electron tube according to the present invention, oxide particles constituting an electron-emitting material layer are distributed without cohesion, and the size of a pore is no greater than 10 μm. Accordingly, a cathode according to the present invention has a uniform distribution of the sizes of particles and pores. A surface roughness of a cathode, measured as a distance between the highest point and the lowest point on the surface of an electron-emitting material layer, is preferably not greater than 10 μm. To attain such a roughness, the carbonate paste can be applied by printing, electrodeposition or painting, most preferably printing. In other words, when an electron-emitting material layer is attached to a base metal, any method of applying predetermined pressure can be used. For example, a printing or deposition method can be used. The printing method is most preferable. Screen printing or roll coating can be used as the printing method.

When the carbonate paste containing the needle-shaped conductive material is applied on the metal base by spraying, the cathode has a surface roughness of approximately 20 μm due to cohesion between particles and a nozzle of a spray gun may clog, making practical use difficult. Also, since the coated surface is coarse,

an image quality may deteriorate due to a Moire phenomenon. Further, a change in potential difference between the cathode and a G1 electrode and a reduction of charge emissions cannot be avoided.

The thickness of an electron-emitting material layer applied is preferably in the range of 30 to 80 μm to obtain good electron emission characteristics without a great change in Braun tube manufacture conditions. If the thickness of an electron-emitting material layer is less than 30 μm, the temperature of the cathode surface is extremely elevated, resulting in poor life characteristics. If the thickness of an electron-emitting material layer is greater than 80 μm, the temperature of the cathode surface is too low to obtain good electron emission characteristics due to poor decomposition of carbonate during evacuation.

A cathode for an electron tube according to the present invention has compactness 2-3 times better and surface roughness about 2 times better than a conventional cathode. Consequently, while the thickness of an electron-emitting material layer can be greatly decreased, the shrinking of a cathode due to a long operation can be prevented, thereby improving a life characteristic and degradation of brightness, and defects caused by a difference between a voltage applied to a cathode and a voltage applied to a G1 electrode can be prevented.

In an embodiment of the present invention, an electron-emitting material layer is attached to a base metal by screen printing. As for screen printing, gauze formed of silk, nylon, Teflon or stainless steel is fasten to a frame to form a screen, which is made to have a portion transmitting ink and a portion not transmitting ink. Therefore, printing is performed by extruding ink to a surface of an object, on which printing is performed, through the screen using a squeegee. Screen printing is characterized by a flexible screen, small printing pressure, and a thick ink coating so that printing can be performed regardless of the material of an object, on which printing is performed, and printing can be performed on a curved surface. Screen printing can be applied to various fields from paper to industrial printing such as plastic sheet and printed wiring boards. In the embodiment of the present invention, printing is performed by a screen printing machine operating according to the above

principle, using a paste obtained by mixing a powder material having coprecipitated carbonate and needle-shaped conductive powder with appropriate binder and organic solvent, instead of using ink.

The resulting cathode is assembled into an electron gun by a general method, followed by mounting on a screen funnel, evacuating and activating, thereby finally yielding an electron tube.

Hereinafter, the effects of the general characteristics of a cathode for an electron tube according to the present invention will be described through embodiments.

<Example 1>

60 g ternary carbonate, in which the percent by weight of Ba:Sr:Ca is 57:30:4, 0.1 g carbon nanotube (CNT), 1 g nitrocellulose, and 39 g terpinol were mixed using an agitator and a roll mill, thereby preparing a printing paste. A base metal (cap) formed of nickel was coated with the paste using a screen printing machine (LS-34TV of Newlong in Japan). Printing pressure was 2-3 kgf/cm^2, and the distance between the gauze of the screen printing machine and the cap was about 1.5 mm. The resulting structure was dried in the atmosphere at 150°C, thereby completing a cathode.

The section and surface texture of an electron-emitting material layer of the cathode prepared above were observed through electron microscopy photographs. FIG. 6 is a photograph of the section enlarged 400 times, and FIG. 7 is a photograph of the surface texture enlarged 3000 times. As compared to FIGS. 2 and 3, the sizes of particles and pores are uniform, and the texture is compact.

<Example 2>

Before printing the carbonate paste on a metal base, a paste for forming a metal layer, the paste obtained by homogenously mixing 10 g nickel powder, 0.4 g tungsten powder, 0.01 g aluminum powder, 0.1 g nitrocellulose and 5 g terpinol, was screen printed on the metal base to a thickness of 2 μm. An electron-emitting material layer was formed on the metal layer in the same manner as in Example 1.

<Example 3>

A cathode for an electron tube was prepared in the same manner as in Example 2, with the exception that a metal layer was printed with a gauze pattern.

<Example 4>

A cathode for an electron tube was prepared in the same manner as in Example 1, with the exception that carbon fiber was used instead of CNT.

<Example 5>

A cathode for an electron tube was prepared in the same manner as in Example 2, with the exception that carbon fiber was used instead of CNT.

<Example 6>

A cathode for an electron tube was prepared in the same manner as in Example 2, with the exception that needle-shaped indium tin oxide powder was used instead of CNT.

<Example 7>

A cathode for an electron tube was prepared in the same manner as in Example 2, with the exception that nickel filament was used instead of CNT.

<Example 8>

A cathode for an electron tube was prepared in the same manner as in Example 2, with the exception that platinum filament was used instead of CNT.

<Comparative Example 1>

A composition typically used for spraying was prepared. The composition contained 40-50% by weight carbonate powder, 0.3-0.4% by weight nitrocellulose, 50-55% by weight isoamylacetate, and 5-5.5% by weight diethyloxalate. An electron-emitting material layer was attached by a spraying method. A spray booth was maintained at a temperature of about 80°C and a pressure of 2-5 kgf/cm^2. The resulting structure was dried in the atmosphere at 150°C. The electron microscopy photographs of the section and surface texture of the electron-emitting material layer are shown in FIGS. 2 and 3.

<Comparative Example 2>

A cathode for an electron tube was prepared in the same manner as in Comparative Example 1, with the exception that 10% by weight of spherical nickel particles were added to the composition.

The characteristics of the cathodes prepared in the above Examples and Comparative Examples are analyzed as follows.

(1) Life characteristic

A change in the IK of each cathode according to the passage of time was measured under cathode loading conditions in which the voltage, operating temperature and initial current density of the heater of each cathode were set to 6.9 V, 760°C and 5 A/cm^2, thereby estimating the life characteristic of each cathode from the residual rate of IK for a predetermined time. Usually, the life of a cathode is defined by mean time to failure mode (MTTF), time which is taken for the residual rate of IK to reach 50%. FIG. 8 shows the evaluation result of life characteristics at a high current density of 5 A/cm^2, and FIG. 9 shows a mean time to failure (MTTF) mode estimated from the evaluation result of life characteristics of cathodes at a high current density of 5 A/cm^2. While the life of the conventional cathode (Comparative Example 1) was 4,000-5,000 hours, the life of each cathode according to the present invention was 20,000-25,000 hours. It can be derived from this fact that the life characteristics of cathodes according to the present invention are markedly increased compared to the life of conventional cathodes. In addition, a decrease in evaporation of barium (Ba) and a decrease in a cut-off drift rate were nearly zero. FIG. 10 shows a variation in cut-off voltages after cathodes are driven for 5000 hours compared to the case of not driving a cathode.

It is understood that a deterioration in operating time dependent emission characteristics of the cathode according to the present invention is greatly reduced compared to the conventional cathode. It is also confirmed that the cathode according to the present invention has very good life characteristic at a high current density of A/cm^2.

(2) Initial emission characteristic

The initial emission characteristic is used to evaluate the electron emission ability or defectiveness of a cathode for an electron gun immediately after production of an electron tube. The initial emission characteristic is generally estimated as the cathode emission current when a predetermined voltage is applied to the cathode and each electrode of an electron gun at the standard operating temperature, that is, at a heater voltage of 6.3 V.

FIG. 11 shows the evaluation result of the initial emission characteristics. Referring to FIG. 11, even if the cathode according to the present invention contains a lesser conductive material than the conventional cathode of Comparative Example 2, its life characteristic improves and the amount of its electron emission material is relatively increased. Therefore, it is confirmed that initial emission characteristic of the cathode according to the present invention improves.

(3) Surface roughness

The distance between a highest point and a lowest point was measured in an about 200 to 500-magnification electron microscopy photograph of the section of each oxide cathode. As a result, the distance was no greater than 8 μm in the cathodes of Examples 1 and 2, while the distance was 20 μm in the cathodes of Comparative Examples 1 and 2.

(4) Distribution of the sizes of pores

The distribution of the sizes of pores was obtained by measuring a ratio of the area of pores to a predetermined area in an about 3000-magnification electron microscopy photograph of each cathode. As a result, the cathodes of Examples 1 and 2 had pores of which the size was no greater than 5 μm, and the cathodes of the Comparative Examples had pores of which the size was about 20 μm.

(5) Distribution of the size of an aggregation of particles

The aggregation of particles was observed from an about 3000-magnification electron microscopy photograph of each cathode. As a result, in the cathodes of Examples 1 and 2, carbonate particles having a size of 5-7 μm were separately distributed without aggregation. In the cathodes of Comparative Examples 1 and 2, particles aggregated to a size of about 30-50 μm.

It is understood that improvement in life and cut-off voltage characteristics and picture quality results from that generation of Joule heat due to intrinsic resistance of an electro-emitting material layer containing a needle-shaped conductive material is minimized, a voltage difference due to the nonuniform distance between a cathode and a G1 electrode is minimized, and the subsidence and shrinking of pores within the cathode is prevented, even if the cathode is used for a long time, because the electron-emitting material layer has a more compact surface and a smaller surface roughness.

As described above, by minimizing generation of Joule heat due to self-heating such that a conductive path is effectively formed by comprising a needle-shaped conductive material in an electron-emitting material layer, and by controlling the sizes of particles and pores constituting the electron-emitting material layer to be uniform and controlling the density and porosity of the electron-emitting material layer, a cathode for an electron tube according to the present invention is improved in compactness and surface evenness compared to a cathode prepared according to a conventional spraying method. Accordingly, shrinking of a cathode during operation can be prevented, and the distance between the cathode and a G1 electrode can be maintained uniform, so that the present invention greatly extends the life of a cathode and realizes a stable electron emission characteristic. Therefore, the present invention can markedly improve the life characteristic of a cathode even in an area of high current density attendant upon the high definition and large scale of recent television Braun tubes.